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Case study

Method of assessment quality protective and decorative coating concrete cement

Loganina Valentina Ivanovna*, Makarova Ludmila Viktorovna, Tarasov Roman Viktorovich

Penza State University of Architecture and Construction, Street Herman Titov, 28, Penza 440028, Russia

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ABSTRACT

The technique of assessing the quality of the painted surface of cement concrete. The technique is based on acceptance sampling quality and is to determine the average and standard deviation (SD) of quantitative assessments of various quality parameters and calculating the real defect level (percentage of defective surface of the total area) for each indicator. The formulas for calculating the defect level. The critical fraction nonconforming surface area coverage for individual properties.

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1. Introduction

The resistance and actual life of protective and decorative coatings often do not correspond to the forecasted. One of the reasons of this discrepancy is lack of proper control over the painted surface quality, especially concrete and plaster ones, which have a higher surface defects concentration compared to the metal one [6].

2. Methodology

It is known, that the variability of paint and varnish materials properties [6] follow the normal law of distribution. Supposing, that the levels of the discrepancies of the coating protective and decorative properties parameters make q_1 and q_2. The probability that the painted surface will be good according to both parameters is equal [4,5,1–3]:

$$P = (1 - q_1)(1 - q_2) \tag{1}$$

Eq. (1) corresponds to the production without defects.

The method of the statistical acceptance control of the construction products and connections painted surfaces is proposed. The technique is based on the control of the particular areas of the surface. The number of areas is determined by calculating.

The technique is based on the definition of average and standard deviation (SD) of quantitative assessments of different quality parameters and on the calculation of the real defect level (percentage of poor areas of the surface) according to each parameter.

* Corresponding author.
E-mail addresses: loganin@mail.ru (L. Valentina Ivanovna), mak.78_08@inbox.ru (M. Ludmila Viktorovna).

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According to normative documents (GOST 9.414-2012 “A uniform protection system from corrosion and ageing. Paint coatings. A method of evaluating the appearance.”) the quality of the painted surface is rated by generalized quantitative estimates of decorative AD and protective AP properties.

Estimate of the AD and AP are calculated by the indicators that characterize the following properties of coatings:

- color change (C);
- gloss change (G);
- shoaling (S);
- mud deduction (M);
- weathering (W);
- perishing (P);
- peeling (Pe);
- blistering (B).

The value of the generalized assessment of the properties of decorative coatings was calculated by the formula

$$AD = XaC + XaG + XaS + XaM \tag{1}$$

where X is a weighting factor of each property C is color change, G is gloss change, S is shoaling and M is mud deduction, C is color change, G is shoaling, S is mud deduction and M is gloss change.

The value of the generalized estimation of AP coatings’ protective properties was calculated by the formula

$$AP = X(0{,}6aP + 0{,}4a\text{ЛП}) + X(0{,}6aW + 0{,}4a\text{ЛП}) + X(0{,}6aB + 0{,}4a\text{ЛП}) + X(0{,}6aPe + 0{,}4a\text{ЛП}) \tag{3}$$

where X is a weighting factor of each type of fracture; aЛП is a relative estimation of damages (diameter, depth); P is perishing; W is weathering; Pe is peeling and B is blistering.

There is a set of a quantitative assessment scale for each parameter depending on the coating condition.

The top border of a good condition of coatings' decorative properties is accepted under condition of AD = 1, the bottom border—at AD = 0.7.

The top border of a good condition of coatings' protective properties is accepted under condition of AP = 1.0, the bottom border—at AP = 0.76.

By a good area we will understand the area of the surface corresponding to the requirements specified according to all the parameters. Consequently, the main requirement, which will determine other requirements, is the requirement for the quality of the painted surface as a whole, which is formulated as follows: “The percentage of poor surface should not exceed q %”.

The solution to the problem of determining the defect levels for a particular area is as follows.

Supposing, the quality of the painted surface is characterized by m properties. Then the probability that the surface will be good according to all the parameters is defined as follows:

$$P = (1-q) = (1-q_1)\cdot(1-q_2)\cdot\ ...\ \cdot(1-q_m) \tag{4}$$

where: $q_1, q_2, \ ...\ , q_n$—the areas of the surface which is poor according to a particular property and q is the area of the surface which is poor according to all the properties.

Expression (1) corresponding to the proportion of all surface quality parameters in control, obviously, is transformed into the inequation:

$$P = (1-q) > (1-q_1)\cdot(1-q_2)\cdot\ ...\ \cdot(1-q_m) \tag{5}$$

In Eq. (5) will be a criteria to accept or reject the painted surface.

Let us consider a particular case when all the properties of the coating are equal, i.e. $q_1 = q_2 = \ ...\ = q_m = q^*$. Then, solving in Eq. (4), we will determine the critical levels of discrepancies for each property:

$$q* < 1 - \sqrt[m]{1-q} \tag{6}$$

Table 1
The critical levels of the coating discrepancies for a particular property (q^*).

Number of quality parameters m	The determined share of defective surface		
	0,01	0,05	0,1
2	$5{,}013\times10^{-3}$	0,025	0,051
4	$2{,}509\times10^{-3}$	0,013	0,026
6	$1{,}674\times10^{-3}$	$8{,}512\times10^{-3}$	0,017
8	$1{,}256\times10^{-3}$	$6{,}391\times10^{-3}$	0,013
10	$1{,}005\times10^{-3}$	$5{,}116\times10^{-3}$	0,01

Table 2
The quantitative assessments of particular properties of the coating.

No. area	No. property				
	1	2	3	. . .	m
1	S_1^1	S_2^1	S_3^1	. . .	S_m^1
2	S_1^2	S_2^2	S_3^2	. . .	S_m^2
3	S_1^3	S_2^3	S_3^3	. . .	S_m^3
. . .	. . .	. . .	. . .	. . .	. . .
n	S_1^n	S_2^n	S_3^n	. . .	S_m^n
	S_1	S_2	S_3		S_m
	σ_1^S	σ_{S_2}	σ_3^S		σ_{S_m}

3. Results

The possible inequation solutions (4) are shown in Table 1.

Table 1 Being guided by the producer and consumer risks α and β (tolerable alpha and beta errors), and also critical levels of discrepancies for good and poor coatings (q_0 and q), we determine the sample number (number of controlled areas of a surface) by formula [4].

$$n = \left(\frac{u_{1-\alpha} + u_{1-\beta}}{u_{1-q_0} - u_{1-q_1}} \right)^2 \tag{7}$$

where: $u_{1-\alpha}$, $u_{1-\beta}$, u_{1-q_0}, u_{1-q_1}—quantiles of the standard normal distribution of corresponding levels.

Having drawn random samples from n areas of the painted surface we determine the quantitative assessment of specified properties for each area [3]:

$$\bar{S}_i = \frac{\sum_{j=1}^{n} S_i^j}{n}, \tag{8}$$

$$\sigma_{S_i} = \sqrt{\frac{\sum_{j=1}^{n} \left(S_i^j - \bar{S}_i \right)^2}{n-1}} \tag{9}$$

where: S_i^j—a quantitative assessment of i property for j area, and n is the number of areas.

The assessment and calculation results are shown in Table 2.

Then the real defect level for each property is calculated by formula:

$$q_i = 1 - \Phi\left(\frac{\bar{S}_i - S_{\mathrm{cr}_i}}{\sigma_{S_i}} \right) \tag{10}$$

where: Scr_i is the set critical value of i property of the coating and $\Phi(x)$ is the value of normal standard distribution function.

Having defined the real values q_i for properties, we compare them with the values specified by the requirements and draw conclusions about the quality of a coating by particular properties.

If the requirements specified the quality of the coating as a whole (by all the properties), then we determine the value q and either accept or reject the coating.

4. Findings

Based on the foregoing, we have developed the method of a statistical quality control of construction products painted surfaces. The main advantages of the proposed method, in our opinion, are the relatively low cost (n = 3 . . . 7), an objective assessment based on the statistical rules, the possibility to analyze the quality of the coating of the surface and also regulate technological processes of painting with the help of control cards and therefore ensure against defects by making technology changes according to the data resulting from control.

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